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NIKE ZEUS AUTOMATIC DESTRUCT RANGE SAFETY PROGRAM FOR THE IBM 7090 COMPUTER

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NIKE-ZEUS AUTOMATIC DESTRUCT RANGE SAFETY PROGRAM
FOR THE IBM 7090 COMPUTER

ABSTRACT

The computer accepts input data from four sources. The first of these sources called System A, consists of an AN/FPS-16 radar, which is slaved to a Cotar. The radar outputs range only and the Cotar outputs direction cosines alpha and beta. System B is the Missile Tracking Radar (MTR) which outputs raw polar data at the rate of 8.123 samples per second. The MTR was designed and is operated by the project personnel of Western Electric Corp. System C is the AN/FPS-16 radar of System A when it is released by the Cotar and is free to track skin and to output polar coordinate data. A second AN/FPS-16 radar, free to operate in the skin-track mode, is identified as System D. Systems A and D together make up the Pacific Missile Range (PMR) system which is input at the rate of 20 samples per second.

A single system is chosen to control destruct computations and impact predictions. The choice is based on data quality as determined by comparing rates of change in position and differences in velocity with predetermined standard, resolving the relative qualities of the data of the four systems with the ranking of the system reliabilities which are in the order A, B, C, D.

Since the MTR samples only at a rate of 8.123 samples per second, redundant data is received when there is no new tracking information. When a new data sample is sent, it is flagged as such for the computer. Space position is computed only on new data samples, but the MTR on-target indication is checked at a 20-sample-per-second rate.

The final output from the computer is a real time recorded history tape that contains all raw tracking information and all computed information from the four systems. This tape may be used later to simulate the missile flight or to output postflight missile data.

FOREWORD

The NIKE-ZEUS Range Safety Automatic Destruct Program was designed to provide a means of range safety control of the NIKE-ZEUS Anti-Missile Missile. Since this missile has a very high acceleration at lift off and since it is ground guided, the range safety problem is increased considerably. The velocity and acceleration of the missile is so high that human reaction is not quick enough to destroy an unsafe missile and contain the resulting fragments within a safe area. Consequently, an automatic destruct system had to be devised to provide safety measures for this type of danger. It was therefore specified that the range safety computer be capable of destroying an unsafe missile automatically.

The incorporation of an automatic destruct system in a range safety computer is a very broad and complex problem. Since a program of this type has never been attempted at Point Mugu, a contract was awarded to Aeronutronics Corp., a division of the Ford Motor Co. at Newport Beach California to study the problem and to submit a proposal to the Range Safety Officer at Point Mugu.

The programing was developed by R. Holguin and T. Rickman in a comparatively short time. Land-Air received the program specifications from Aeronutronics on 8 January 1962, and the program was ready for Range Safety checkout on 19 February 1962.

Because of the increased speed of the IBM 7090 over the 709, and also because of the experience gained from the earlier program, computation time for the automatic destruct program has been reduced considerably. The 709 program took approximately 46 milliseconds of computation time for three systems, and the more complex 7090 program takes approximately 18 milliseconds of computation time for four systems. The program uses approximately 21894 cells of core memory, of which approximately 12000 are tables.

Although reprograming the NIKE-ZEUS problem for the computer was accomplished in near record time, it could not have been done without the devoted efforts of the following people: Mr. P. Rotsheck of Cubic Corp.; Mr. B. Larey, Mr. C. LeRoy and Mr. J. Harvey of Range Development Dept.; Mr. R. Long and Mr. R. Wilkerson of IBM Corp.; Mr. J. Yost of Bell Telephone Labs; Mr. L. Powell of Western Electric Co. Many other people devoted their time and effort to this project, but their names are too numerous to mention here. Sections 1, 2, and 3 were taken with appropriate changes from Land-Air, Inc. Report 26, "Computer Programing for Real Time Impact Prediction and Destruct Control." The report was edited and prepared for publication by Mr. T. Wakai of Land-Air, Inc.

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1 INTRODUCTION

This is a real time digital computer application to predict impact location and to control the missile destruct device. Working from the input sources the computer edits the data it receives, selects a sample and computes the information required for output. Among this output is information for driving three remotely located plotting boards, data quality lights and a signal to a destruct control device.

1.1 DESTRUCT PHILOSOPHY

The destruct philosophy is to destroy any missile that appears to endanger the mainland or any island except San Nicolas Island and Anacapa Island or appears to be leaving the predetermined boundaries of the missile range. The destruct on minimum downrange velocity is designed to protect against turns toward the mainland. The destruct on fragment impact points is designed to protect islands and prohibit the missile from leaving the confines of the Pacific Missile Range. Destruct will also be commanded if the computer loses data from all tracking systems caused by tracker failure or transmission failure, for it would not be safe to allow a highly maneuverable missile to wander around if reliable information about its position is not known. The criteria for sending a destruct command will be described later in this document.

1.2 SYSTEM HARDWARE

Figure 1 presents the major parts of the system's equipment. The input and output equipment is shown only in very minor detail and is so treated throughout this manual, with emphasis reserved for the central subject, the computer programing. The purpose of this publication, therefore, permits no more than reference to such important components of the total system as the Cubic DH-10 Digital Distribution Units (DDU), Input/Output Buffer, DH-14 Digital Multiplex Synchronizer (DMS); the Collins transmission equipment; and the contributions from the Range Development Department of PMR.

1.3 VOICE COMMUNICATIONS

In addition to the data system, there are two voice communication networks detailed for use by the system's operating personnel. These circuits, identified as 705 and 706, are shown in Figure 2. In general, network number 705 is the input network and includes a phone jack at the DDU rack at each tracking site in addition to those shown. Conversely, network 706 is used by personnel whose major concern is output. Note that station 4 is patched into both nets.

The telephone positions are serially numbered with the numbers circled and located in the illustration approximately at the users working station.

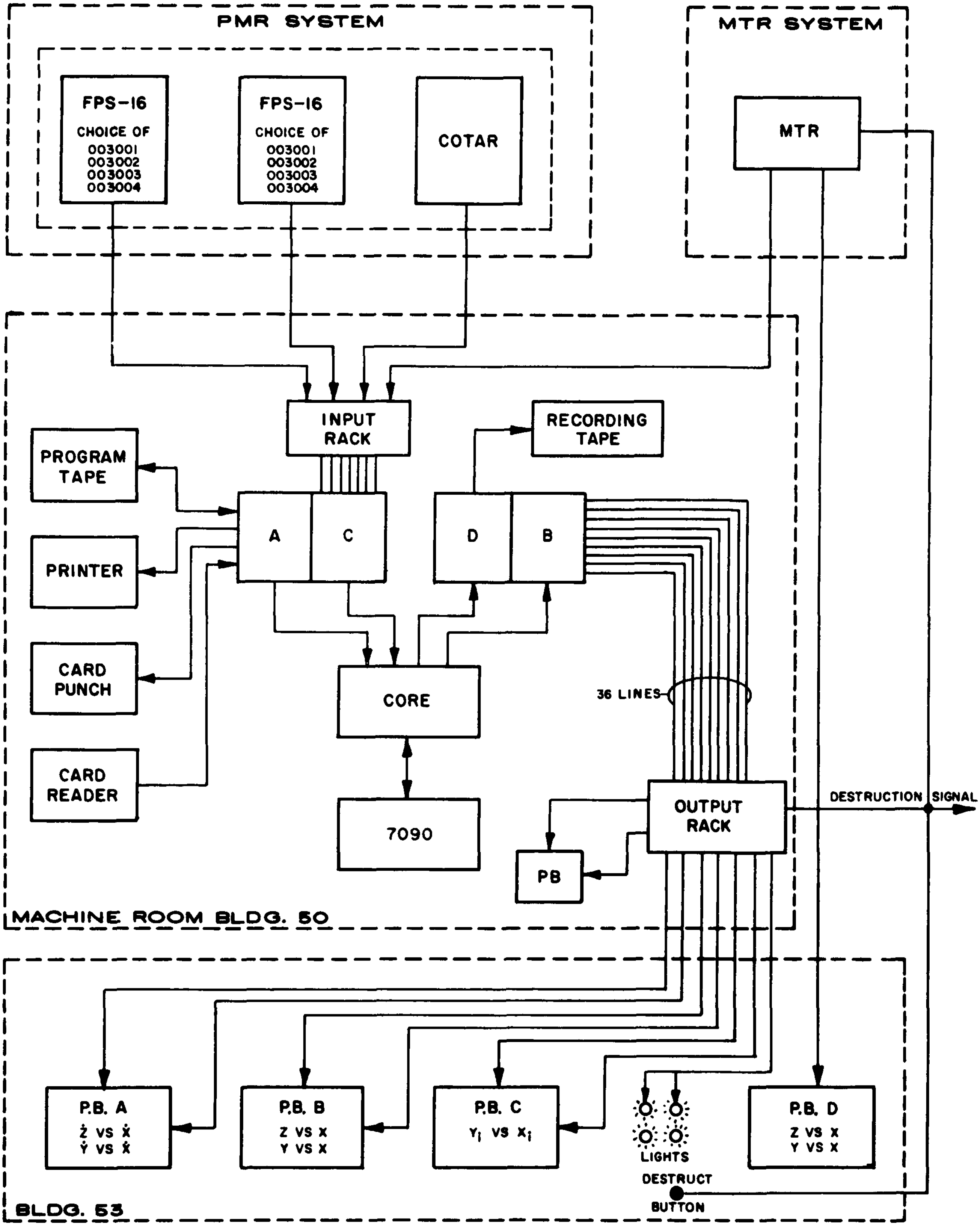
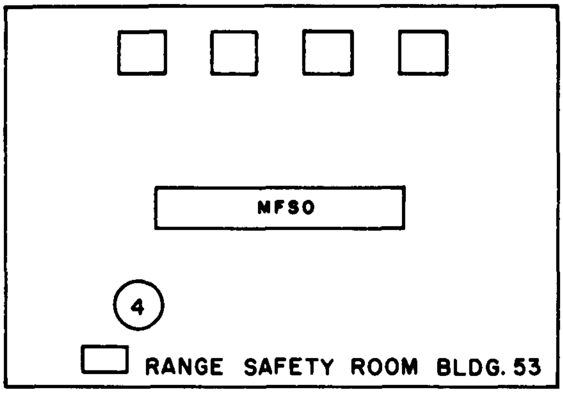


Figure 1. Range Safety System



NETWORK	STATION	USER
705	1	R.O. EQUIPMENT TECHNICIANS
	2	" " "
	3	" " "
	4	LAI COMPUTER CONTROLLER
706	4	" " "
	5	COMPUTER OPERATOR
	6	TAPE HANDLER
	7	LOGGER
	SPACE	UNASSIGNED

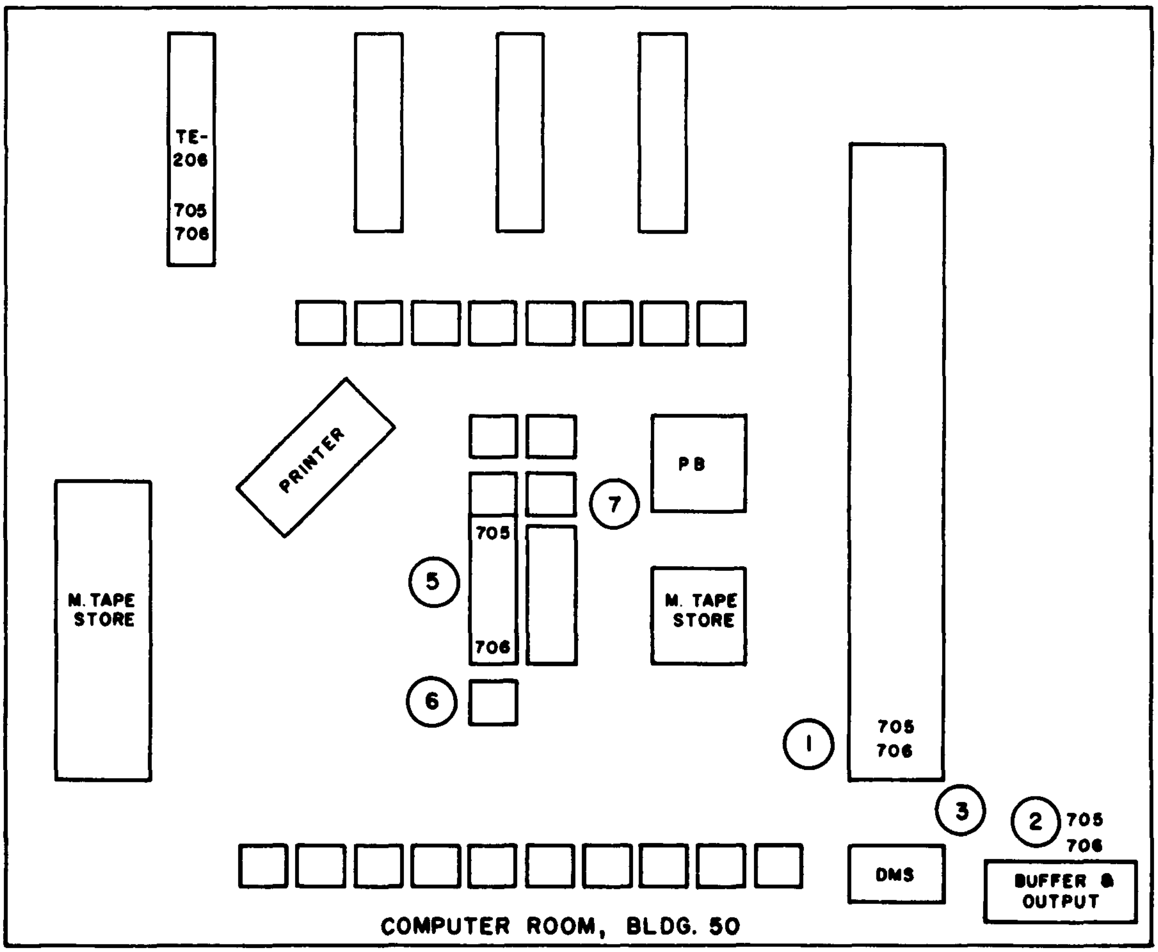


Figure 2. Voice Communications

1.4 COMPUTER PERSONNEL

Personnel manning these stations are as follows:

1.	Equipment technical	Range Operations Department
2.	Equipment technical	Range Operations Department
3.	Equipment technical	Range Operations Department
4.	Computer controller	
5.	Computer console operator	
6.	Tape handler	
7.	Logger	
Spare	Unassigned	

The computing function requires a crew of four people: the console operator, who is in charge of the computer operation, the tape handler, the logger, and the computer controller. The computer controller is located, not in the computer room, but in Building 53, near the output displays.

1.5 PROGRAMING

The computer was programed and checked out by the Land-Air programing staff from specifications prepared under another contract by Aeronutronic. The program is built with facility for selecting automatically from 4 systems.

There are a number of constants that must be entered in the program prior to the operation. These constants are determined by others and given to the programer. The effect of admitting these constants to the program resembles more a program modification than a single insertion or switch. This information is, therefore, given the programer several days in advance of the operation.

1.6 PREOPERATION CHECKOUT

The preoperation checkout consists of component checks, partial system checks and an end-to-end check. The computer checkout is a procedure that requires from three to four hours to complete. It is run completely on the day before the operation and is repeated on the day of the launch and finished, by plan, at least fifteen minutes prior to liftoff.

1.6.1 Customer Engineer's Check

The computer with all its components, is prepared for use by the manufacturer's customer engineers (CE's) who run their diagnostic programs and make any adjustments thereby discovered necessary. This is a procedure that consumes 30 to 45 minutes. The computer is then turned over to the operators.

1.6.2 Tape Handler's Preparations

At the same time, the tape handler cleans the magnetic tape heads and readies the tapes. The latter consists of selecting six reels of degaussed tape, and stripping and removing scratched or worn tape from the leader end to a point where good clean tape begins. He also mounts the program tape, impact constants tape and the first of the simulator trajectory tapes.

Also at the same time, the output equipment and the plotting boards are undergoing independent checkout procedures.

1.6.3 Check Sum Comparisons

There are two points of interest in checking out the computer; reading the program and impact tables into core, and inputting simulated data. Both are programed to be checked through use of the check sum techniques.

1.6.3.1 Core Check

When the operating program, including a check sum word, has been read into core, a logical summation is made of the program words entered. The results of this summation is then compared with the check sum word. Any difference is flagged by a statement printed out on-line. The cause for difference is found and removed. The procedure is also applied to the transfer of tables to core and assures the correct transfer of this information.

1.6.3.2 Program Check

The other point of interest in computer checkout consists of running the program, using simulated input. Four tapes containing thirty seconds each of raw computer input data, identified as Case I through Case IV, have been furnished by Aeronutronic for this purpose. Case I contains data representing a perfect flight through the planned trajectory. The flight represented by the Case II data develops an $\dot{X}$ velocity component smaller than $\dot{X}_{min}$, the specified minimum, and results in destruct signals. Case III also ends in destruct signals but as a consequence of the trajectory straying outside the safe impact area. Case IV contains loss of track or bad data in one or more inputs so the complete problem logic is tested.

1.6.3.2.1 Standard Tapes

Each of these tapes has been processed by the program to produce output tapes. The first thirty words of each record consists of the raw input; the remainder, computed output. All errors in the program have been found and corrected. When the computer is functioning at par, it can recreate any of these output tapes. Therefore, these tapes qualify as standards and are so used.

1.6.3.2.2 Tape Comparison

The original checkout of the program to produce the standard tapes was heavily consumptive of personnel time. The manual check of subsequent checkout tapes against the standard would be a prohibitive time consumer. Hence, this work is given to the computer for which a program is coded to make such a comparison using the logical check sum technique.

Whenever the program finds disagreement between the newly run output tape and the standard tape the fact is printed out on-line. The program is stopped and the cause of the disagreement is examined. As the program is continually improved and experience with it grows, it becomes decreasingly the cause of disagreement in this checkout procedure. At the same time, the procedure becomes, more positively, a check on the computer itself.

1.6.4 Check Output to Plotting Boards

When the computer is checked out, the output system and plotting boards are placed on-line and the four simulated input tapes are rerun. At this stage, the computer controller can observe the output at the remotely located plotting boards where the pens track out the familiar traces in response to the program and simulated data. This test serves as an independent check on the earlier warmup and checkout of the output and transmission facilities and of the plotting board calibrations. It also provides an independent view of the computer program performance.

1.6.4.1 System Checkout With Radars

The final step is the integration of the total system where the input instruments are placed on-line to enable a real time test. The test proceeds by operating the radars and cotar according to instructions from the computer controller. A typical request by him of the radar operator would be to direct the radar beam to the launch pad and set in a constant range, such as the known range from the radar to the pad. Then, outputting this range, the operator would be asked to slew through 360° of azimuth. When the complete system is operating properly, such an input would produce a circular trace on the plotting board chart. The trace turns about the radar site as a center, and begins and ends at the launch pad. Both of these points are preplotted on the (X,Y) chart. The radar operator would again direct the beam to the launch pad and slew the beam upward through sixty or more degrees of elevation angle. This action, since the radar is located near the Y axis, would produce a vertical line from the launch pad representation on the (X,Z) chart. The operation is repeated for all radars except the one slaved to the cotar.

1.6.4.2 System Checkout With Cotars

The radar-cotar input is tested in another manner. A beacon, aboard an aircraft, transmits a signal that the cotar can receive. On receiving the signal, the cotar directs the radar to this point. As a result, the radar sends range and the cotar sends the cosines of α and β to the computer. When the output is processed by the computer program and sent to the plotting boards the pens take the position of the aircraft in flight on the (X,Y) and (X,Z) charts.

1.7 COMPUTER OPERATION

When the checkout procedure is completed satisfactorily, the range safety system is "all green". The program continues to operate by recycling, reading from tape and outputting to tape with the real time inputs disconnected. The real time input sources and the output displays are placed on-line by a console sense switch. The computer operator does this on command of the computer controller. No further human intervention is permitted thereafter. One tape unit is used to record the raw input to the computer for postoperation uses. The unit is idle until the liftoff signal is received.

The digital computer will operate from two independent and unrelated input systems to provide the real time safety services. The logic in the use of these inputs is such that maximum confidence accompanies the computer output when both inputs are functioning. Deterioration or loss of one input system only lowers the confidence level associated with the computer output, but completely reliable output can result from only one good input.

2.1 PMR INPUT SYSTEM

The PMR offers a choice of three separate input systems. They are received at the computer but only one is used in the computations and referred to as the PMR system. The choice is made automatically by the program on a priority basis.

2.1.1 Cotar/FPS-16

An FPS-16 radar and a cotar will comprise one of the choices where the radar is slaved to the cotar. In this union the radar will output range only, with the remaining position information coming from the cotar. Therefore, the cotar will have the dual role of outputting direction cosines as its data contribution, and also information to the radar tracking serves to maintain the radar track. This input system, System A, will then supply range R_F in feet; cosine α, and cosine β. The sampling rate is twenty per second.

2.1.2 FPS-16

The second choice offered by the PMR is an FPS-16 radar alone. These systems, C & D, will input to the computer; range R_F in feet, azimuth angle A_F, and elevation angle E_F, both in degrees, at the rate of twenty samples per second.

2.2 MTR INPUT SYSTEM

The MTR input system, System B, is a component of the missile project. This radar is permanently in the system and outputs range R_M in feet, azimuth A_M and elevation E_M, both in degrees. The sampling rate is about 8.13 per second.

The computer input data appears in a record of thirty 24-bit words. The record is divided into five 6-word fields devoted to timing, elevation angle, range, azimuth, and parity check. Each field is divided into six words. The first word in each field is reserved for AN/FPS-16 radar input. The second word in each field receives the cotar input; the third word, the Missile Tracking Radar (MTR) input; the fourth word the input from the second AN/FPS-16 radar. These record details are further tabulated below.

Computer Words	Information
1. Timing	Range Time FPS-16 radar
2. "	" COTAR
3. "	" MTR
4. "	" FPS-16 radar
5. "	Zero
6. "	"
7. Elevation	Elevation FPS-16 radar
8. "	Corrections COTAR
9. "	Elevation MTR
10. "	Elevation FPS-16 radar
11. "	Zero
12. "	"
13. Range	FPS-16 radar
14. "	Direction cosine COTAR (β)
15. "	Range MTR
16. "	FPS-16 radar
17. "	Zero
18. "	"
19. Azimuth	Azimuth FPS-16 radar
20. "	Direction cosine COTAR (α)
21. "	Azimuth MTR
22. "	Azimuth FPS-16 radar
23. "	Zero
24. "	"
25. Parity	Misc. Information FPS-16 radar
26. "	" " COTAR
27. "	" " MTR
28. "	" " FPS-16 radar
29. "	Zero
30. "	"

3.1 FPS-16 RADAR INPUT FORMAT

Input to the computer from the AN/FPS-16 radar appears in five-word format of 24 bits per word. The usage of these words in the order of their appearance in Figure 3 is as follows:

	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WORD 1	0	X	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{15}	T_{14}	T_{13}	T_{12}	T_{11}	T_{10}	T_9	T_8	T_7	T_6	T_5	T_4	T_3	T_2	T_1
WORD 7	0	0	$\bar{\Phi}$	I_3^0	I_2^0	I_1^0	0	E_{17}	E_{16}	E_{15}	E_{14}	E_{13}	E_{12}	E_{11}	E_{10}	E_9	E_8	E_7	E_6	E_5	E_4	E_3	E_2	E_1
WORD 13	0	0	R_{22}	R_{21}	R_{20}	R_{19}	R_{18}	R_{17}	R_{16}	R_{15}	R_{14}	R_{13}	R_{12}	R_{11}	R_{10}	R_9	R_8	R_7	R_6	R_5	R_4	R_3	R_2	R_1
WORD 19	0	0	I_3^1	I_2^1	I_1^1	I_3	0	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1
WORD 25	P_{BD}	0	$P_{CH_O}^{2}$	I_2^2	I_1^2	X	$P_{CH_E}^{2}$	$P_{CH_O}^{3}$	$P_{CH_O}^{4}$	X	$P_{CH_O}^{1}$	I_2^3	I_1^3	$P_{CH_E}^{1}$	$P_{CH_E}^{3}$	$P_{CH_E}^{4}$	0	0	0	0	0	0	0	0

LEGEND

A	Azimuth	P_{CH}^{n}	Parity (Longitudinal)
E	Elevation	T_N	Time (PMR)
I_N^n	Identification (Octal Code)	T_{VC}	Time (Vernier Count)
$\bar{\Phi}$	On Target	X	Constant "One" Bits
P_{BD}	Parity (Bad Data)	0	Constant "Zero" Bits
R	Range		

Figure 3. AN/FPS-16 Radar Input Format

Record Word 1	First Radar Word	Range Time
Record Word 7	Second Radar Word	Elevation Angle
Record Word 13	Third Radar Word	Slant Range
Record Word 19	Fourth Radar Word	Azimuth Angle
Record Word 25	Fifth Radar Word	Parity Check

3.1.1 Word 1 (First Radar Word)

The integer portion of the binary expression of range time appears as T in bits 21 through 35. The low order bit is 35 which represents two seconds as the finest time expression. The finer portion of the range time expression appears as T_{vc} in bits 14 through 20. These counts change at the rate of 40 counts per second and recycle every two seconds or 80 counts.

Annexing the counts of this, the vernier counter, to the course range time counter it becomes possible to sense range time to a fineness of 0.025 seconds. The vernier counter does not present a direct reading of the fine component of the time, however, since it does not register nor recycle at zero. Instead, the counter progresses to 80 and then returns to 1. It is, therefore, necessary to subtract a binary 1 from a readout of the vernier counter to obtain a reading of the fine component of range time.

The remaining bits, 12 and 13, of Word 1 are as shown in Figure 3 and are of no concern to the computer programing.

3.1.2 Word 7 (Second Radar Word)

This word receives the elevation angle E in bits 19 through 35. A readout of these bit positions results in the expression of a fraction of a circle. The value associated with each bit, beginning with the high order bit 19, is:

$$\pi/2^0,\ \pi/2^1,\ \pi/2^2, \ldots,\ \pi/2^{16}.$$

Bit 14 in this word displays a 0 when the radar is off track and a 1 when the radar is on track. The other bit positions are of no concern to the computer programing.

3.1.3 Word 13 (Third Radar Word)

This word expresses range in yards using bit positions 14 through 35. The low order bit 35, identified as R_1, has the value of 0.5 yards. The series R_1 through R_{21} is associated with the values:

$$2^{-1},\ 2^0,\ 2^1, \ldots,\ 2^{19}.$$

Other bits in this word are unrelated to the computer programing.

3.1.4 Word 19 (Fourth Radar Word)

This word is devoted to the expression of azimuth angles. It is used and described the same as Word 7 except for bit position 14 which has no use in this word.

3.1.5 Word 25 (Fifth Radar Word)

The only part of this word used in the computer processing of the data is the bit appearing in position 12 labeled P_{BD}. This is a parity bit and is interpreted thus:

1 Bad data
0 Good data.

3.2 COTAR INPUT FORMAT

Input to the computer from the Cotar appears in a five-word format of 24 bits per word. The usage of these words in the order of their appearance in the record and in Figure 4 is as follows:

Record Word 2	First Cotar Word	Range Time
Record Word 8	Second Cotar Word	Frequency Corrections
Record Word 14	Third Cotar Word	Cosine β
Record Word 20	Fourth Cotar Word	Cosine α
Record Word 26	Fifth Cotar Word	Parity Check

3.2.1 Word 2 (First Cotar Word)

This word receives the range timing information associated with the Cotar data in a manner exactly the same as Word 1. For details, refer to Word 1 under FPS-16 Radar Input.

3.2.2 Word 8 (Second Cotar Word)

This word contains three unrelated groups of data identified as K_r, K_c and Q. K_r is a constant, K_c is a variable factor, and Q a quality bit.

3.2.2.1 K_r, Transmitter Constant

There exists in the system a Cotar frequency correction term K_r. This correction represents the magnitude of the transmitter frequency deviation from the Cotar design frequency f_b. The value of K_r in megacycles is not transmitted, but is tabled in the computer opposite a set of code numbers as arguments. The term is constant for any transmitter frequency and is introduced by a code, set in bit positions 22 through 26, noted A_{10} through A_{14}. This code is the argument for the table lookup to obtain K_r.

3.2.2.2 K_c, Doppler Compensation

The doppler effect is measured by the Cotar and expressed as single cycles per second. The output of this measuring device appears as a whole number in bit positions 27 through 35, labeled A_1 through A_9.

3.2.2.3 Q, Data Quality

Position 14, labeled Q is a quality bit. This is the output of a device in the Cotar that compares the signal received with a standard determined by the setting of K_r. Bit 14 displays a 1 if the comparison is favorable and a 0 if it is unfavorable. Criteria for making the distinction is a Cotar matter and of no concern to the program. The program accepts or rejects on the basis of this bit, however.

Word	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
WORD 2	0	X	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{15}	T_{14}	T_{13}	T_{12}	T_{11}	T_{10}	T_9	T_8	T_7	T_6	T_5	T_4	T_3	T_2	T_1
											K_R					K_C								
WORD 8	0	0	Q	I	I	I	I	I	I	I	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1
							COS 1 β																	
WORD 14	0	0	I	I	I	B_{19}	B_{18}	B_{17}	B_{16}	B_{15}	B_{14}	B_{13}	B_{12}	B_{11}	B_{10}	B_9	B_8	B_7	B_6	B_5	B_4	B_3	B_2	B_1
							COS 2 α																	
WORD 20	0	0	I	I	I	C_{19}	C_{18}	C_{17}	C_{16}	C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2	C_1
WORD 26	P_{BD}	0	$P_{CH}2$ O	I	I	X	$P_{CH}2$ E	$P_{CH}3$ O	$P_{CH}4$ O	X	$P_{CH}1$ O	I	I	$P_{CH}1$ E	$P_{CH}3$ E	$P_{CH}4$ E	0	0	0	0	0	0	0	0

LEGEND

Q_n	Data Quality	T_N	Time (PMR)
I_N^n	Identification Octal Code	T_{VC}	Time (Vernier Count)
A_N	Data Parameter	X	Constant "One" bit
B_N	Cosine 1 (β)	0	Constant "Zero" bit
C_N	Cosine 2 (α)	P_{CH}^n	Longitudinal Parity
P_{BD}	Parity (bad data)		

Figure 4. Cotar Input Format

3.2.3 Word 14 (Third Cotar Word)

The binary representation of a number that is proportional to the direction cosine β or its complement appears in bit positions 18 through 35, labeled B_1 through B_{18}. Position 17 is a sign bit. If this bit is 0, the contents of positions 18 through 35 are interpreted as proportional to the direction cosine β with a negative sign. If bit 17 is 1, the contents of these positions are interpreted as proportional to the positive one's complement of the direction cosine β. This information is the output from a set of code wheels. The required function is the product of this output multiplied by an instrument constant.

3.2.4 Word 20 (Fourth Cotar Word)

This word is used exactly the same as Word 14 above except the angle α is processed instead of β.

3.2.5 Word 26 (Fifth Cotar Word)

This word is used for the Cotar input in exactly the same manner as Word 25 serves the FPS-16 Radar Input.

3.3 MISSILE TRACKING RADAR INPUT FORMAT

Input to the computer from the Missile Tracking Radar (MTR) appears in a five-word format of 24 bits per word. The usage of these words in the order of their appearance in Figure 5 is as follows:

Record Word 3	First MTR Word	Range Time
Record Word 9	Second MTR Word	Elevation Angle
Record Word 15	Third MTR Word	Slant Range
Record Word 21	Fourth MTR Word	Azimuth Angle
Record Word 27	Fifth MTR Word	Parity Check

3.3.1 Word 3 (First MTR Word)

This word receives the range timing information associated with the MTR data in a manner exactly the same as in Word 1. For details, refer to Word 1 under FPS-16 Radar Input.

3.3.2 Word 9 (Second MTR Word)

This word receives the elevation angle E in bits 18 through 35. A readout of these bit positions results in the expression of a fraction of a circle. The value associated with each bit, beginning with the high order bit 18, is:

$$\pi/2^0,\ \pi/2^1,\ \pi/2^2, \ldots,\ \pi/2^{17}.$$

Bit position 14, labeled S, signals liftoff in addition to on and off track. Initially the position is inactive. At liftoff the position displays a 1. Thereafter, throughout the operation, this bit is interpreted as follows:

WORD 3

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0	X	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{VC}	T_{15}	T_{14}	T_{13}	T_{12}	T_{11}	T_{10}	T_9	T_8	T_7	T_6	T_5	T_4	T_3	T_2	T_1

WORD 9

0	0	$\bar{\Theta}$	I_3^0	I_2^0	I_1^0	E_{18}	E_{17}	E_{16}	$\dot{E}_{15}$	E_{14}	E_{13}	E_{12}	E_{11}	E_{10}	E_9	E_8	E_7	E_6	E_5	E_4	E_3	E_2	E_1

WORD 15

0	0	R_{22}	R_{21}	R_{20}	R_{19}	R_{18}	R_{17}	R_{16}	R_{15}	R_{14}	R_{13}	R_{12}	R_{11}	R_{10}	R_9	R_8	R_7	R_6	R_5	R_4	R_3	R_2	R_1

WORD 21

0	0	I_3^1	I_2^1	I_1^1	I_3	A_{18}	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1

WORD 27

P_{BD}	0	$P_{CH\,O}^{2}$	I_2^2	I_1^2	X	$P_{CH\,E}^{2}$	$P_{CH\,O}^{3}$	$P_{CH\,O}^{4}$	X	$P_{CH\,O}^{1}$	I_2^3	I_1^3	$P_{CH\,E}^{1}$	$P_{CH\,E}^{3}$	$P_{CH\,E}^{4}$	0	0	0	0	0	0	0	0

LEGEND

A	Azimuth	P_{CH}^{n}	Parity (Longitudinal)
E	Elevation	T_N	Time (PMR)
I_N^n	Identification (Octal Code)	T_{VC}	Time (Vernier Count)
$\bar{\Theta}$	On Target	X	Constant "One" Bits
P_{BD}	Parity (Bad Data)	0	Constant "Zero" Bits
R	Range		

Figure 5. Missile Tracking Radar Input Format

0 Off Track
1 On Track

The computer program is concerned with no other bits in this word.

3.3.3 Word 15 (Third MTR Word)
The major use of Word 15 is to receive slant range. The low order bit in bit position 35 as received has the value .09367972 meters which is treated in the program as .30734815 feet. The range is thus treated in these terms with bit position 15 noted R_{S1} as the high order bit.

The MTR samples at a rate of 8.123 samples per second but the program is designed for a sampling rate of twenty samples per second. In order that it process only new data it will test on bit position 14, labeled R_{S2}. A new data sample will introduce a 1 in this position which will change to a 0 when the sample has been processed.

No other parts of this word concern the computer program.

3.3 4 Word 21 (Fourth MTR Word)
This word receives the azimuth angle and is the same as Word 9 except that bit 14 is unassigned. For details beyond this exception, refer to Word 9 of this section.

3.3.5 Word 27 (Fifth MTR Word)
This word is used for the MTR input in exactly the same manner as Word 25 serves the Radar Input.

Before the Cotar data is edited, it must be corrected for the frequency of the NIKE-ZEUS telemetry system. The true direction cosines are computed from the following equations:

$$C_{1T} = K_0 C_1$$

$$C_{2T} = K_0 C_2$$

where

$$K_0 = \frac{1}{\dfrac{K_r + (K_c - 100)\omega}{1 + fb}}$$

where

$C_{1T} \equiv$ TRUE C_1	$K_r \equiv$ COTAR OPERATING FREQUENCY
$C_{2T} \equiv$ TRUE C_2	$K_c \equiv$ FREQUENCY CORRECTION
$C_1 \equiv$ COTAR COSINE BETA	$fb \equiv$ COTAR BASE FREQUENCY
$C_2 \equiv$ COTAR COSINE ALPHA	$\omega \equiv$ FREQUENCY CORRECTION

4.1 PREDICTION

Before the data received is edited, the lockout indication must be checked. If the interval between the first word of the sample from a source that arrives first and the first word of the sample from a source that arrives last is greater than 3.3 milliseconds, lockout occurs. If the lockout indicator shows that a lockout has occurred, no editing is performed; and values for all trackers are predicted using the following equations:

COTAR

$$(\cos\alpha)_{PRED} = \cos\alpha(t - \Delta t) + .05\cos\alpha(t - \Delta t)$$

$$(\cos\beta)_{PRED} = \cos\beta(t - \Delta t) + .05\cos\beta(t - \Delta t)$$

AN/FPS -16

$$R_{PRED} = R(t - \Delta t) + .05\,R(t - \Delta t)$$

$$A_{PRED} = A(t - \Delta t) + .05\,A(t - \Delta t)$$

$$E_{PRED} = E(t - \Delta t) + .05\,E(t - \Delta t)$$

MTR

$$R_{PRED} = R(t - \Delta t) + .123\ \dot{R}(t - \Delta t)$$

$$A_{PRED} = A(t - \Delta t) + .123\ \dot{A}(t - \Delta t)$$

$$E_{PRED} = E(t - \Delta t) + .123\ \dot{E}(t - \Delta t)$$

4.2 EDITING

If the lockout indicator shows that no lockout has occurred, the following editing is performed on raw data. The data is good when the following inequalities are satisfied:

COTAR

A

$$C_{1T}(t) - C_{1T}(t - \Delta t) < \Delta C_{1T}$$

$$C_{2T}(t) - C_{2T}(t - \Delta t) < \Delta C_{2T}$$

B*

$$C_{1T}(t) - C_{1TPRED}(t - \Delta t) < C_{1T}$$

$$C_{2T}(t) - C_{2TPRED}(t - \Delta t) < C_{2T}$$

MTR

A

$$R_m(t) - R_m(t - \Delta t) < \Delta R_m$$

$$A_m(t) - A_m(t - \Delta t) < \Delta A_m$$

$$E_m(t) - E_m(t - \Delta t) < \Delta E_m$$

B*

$$R_m(t) - R_{mPRED}(t - \Delta t) < \Delta R_m$$

$$A_m(t) - A_{mPRED}(t - \Delta t) < \Delta A_m$$

$$E_m(t) - E_{mPRED}(t - \Delta t) < \Delta E_m$$

(This computation is made when new data flag indicates new data. Thus $(t - \Delta t)$ refers to previous point when new data flag indicated new data.)

A

$$R_F(t) - R_F(t - \Delta t) < \Delta R_F$$

$$A_F(t) - A_F(t - \Delta t) < \Delta A_F$$

$$E_F(t) - E_F(t - \Delta t) < \Delta E_F$$

B*

$$R_F(t) - R_{FPRED}(t - \Delta t) < \Delta R_F$$

$$A_F(t) - A_{FPRED}(t - \Delta t) < \Delta A_F$$

$$E_F(t) - E_{FPRED}(t - \Delta t) < \Delta E_F$$

*B is computed only for those variables, if any, that were predicted at the previous sample.

4.3 LOGIC FOR DETERMINING WHETHER SAMPLE IS GOOD OR BAD

The following table shows the logic used to determine whether the new sample is good or bad. This logic must be used in determining the status of each variable of every sample.

The editing performed under A where 0 = good 1 = bad	The editing performed under B where 0 = good 1 = bad	Is the variable good or bad
*	0	good
*	1	bad
0	**	good
1	**	bad
0	0	good
0	1	good
1	0	good
1	1	bad

* This editing is not performed because a lockout occurred on the previous sample and the previous raw data is not reliable.
** This editing is not performed because the variable was not predicted at the previous sample.

If the variable is bad, a predicted variable must be used from the equation given previously under "PREDICTION."

Two additional checks on Cotar data must be made to assist in determining whether or not the Cotar data is acceptable.

One check is defined by the inequality

$$\cos^2 \alpha + \cos^2 \beta > 1 .$$

If the above inequality is satisfied, the Cotar data is bad but no predictions are made for the direction cosines.

The other check, which is computed only when either the MTR or Free AN/FPS-16 has good data, is defined by the following inequality.

If

$$\sqrt{\Delta X^2 + \Delta Y^2} > \Delta P,$$

the Cotar/FPS-16 system is bad;

where

$$\Delta X = X_{Cotar/16} - X_{MTR}$$

$$\Delta Y = Y_{Cotar/16} - Y_{MTR}$$ only if MTR is good and beacon is good for MTR

and

$$\begin{aligned} \Delta P &= .022 R_{FPS-16} && \text{for} \quad 0 < R_{FPS-16} < R_1 \\ &= .022 R_1 && \text{for} \quad R_1 < R_{FPS-16} < R_2 \\ &= .022 R_1 + K_P (R_{FPS-16} - R_2) && \text{for} \quad R_2 < R_{FPS-16} \end{aligned}$$

where

R_1 = 80,000 feet

R_2 = 300,000 feet.

When the above inequalty is not satisfied, data is flagged bad, but we do not predict new variables.

4.4 TIME COMPUTATION

Time from lift off is computed using the equation:

$$t_{CL} = (R_t - R_{t_{LO}}) + t_o$$

where

t_{CL} = Time from lift off

R_t = Current Range Time

$R_{t_{LO}}$ = Range time at lift off

t_o = .031 seconds

For smoothing and differentiation of position data (R, A, E, cos α, cos β) which must be done for each system, the value for R_i is chosen as being typical of the computations to be made on all variables. Moreover, in each case the coefficient that is subscripted 0 multiplies the most recent data point. In those cases where the data point was replaced by a predicted value, the predicted variable should be used in the differentiation.

5.1 THE POLYNOMIAL FILTER USED FOR COTAR AND AN/FPS-16's

$$\dot{R} = \sum_{i=0}^{n} a_i R_i$$

where

$n = 10$

Values for the coefficient a_i for the above polynomial filters are:

FOR COS α AND COS β

$a_0 = 5.7628307$	$a_4 = -1.6260023$	$a_8 = -1.2021071$
$a_1 = 1.1806834$	$a_5 = -1.5259270$	$a_9 = -.08410835$
$a_2 = -.8847345$	$a_6 = -1.4816031$	$a_{10} = 2.8966360$
$a_3 = 1.5672828$	$a_7 = -1.4683728$	

FOR BOTH FPS-16's

RANGE	$a_0 = 7.9725221$	$a_4 = -1.1859405$	$a_8 = -1.1373278$
	$a_1 = -1.6765070$	$a_5 = -1.1054617$	$a_9 = -1.2417558$
	$a_2 = -1.4739212$	$a_6 = -1.0697722$	$a_{10} = 3.3077836$
	$a_3 = -1.3094937$	$a_7 = -1.0801248$	
AZIMUTH	$a_0 = 7.3318873$	$a_4 = -1.2209142$	$a_8 = -1.2262227$
	$a_2 = -1.1507921$	$a_6 = -1.2460577$	$a_{10} = 3.4827484$

ELEVATION	a_0 = 7.3243491	a_4 = -1.2216546	a_8 = -1.2267663
	a_1 = -1.0916883	a_5 = -1.2409514	a_9 = -1.1980127
	a_2 = -1.1470231	a_6 = -1.2482356	a_{10} = 3.4838356
	a_3 = -1.1903451	a_7 = -1.2435073	

5.2 THE POLYNOMIAL FILTER USED FOR THE MTR

$$\dot{R} = \sum_{i=0} N_i R_i$$

where

$n = 4.$

RANGE	N_0 = 8.3731038	N_3 = -3.9396092
	N_1 = -4.6527669	N_4 = 3.9475150
	N_2 = -3.7282431	
AZIMUTH	N_0 = 6.2779017	N_3 = -3.1389505
	N_1 = -1.5113466	N_4 = 3.0226941
	N_2 = -4.6502974	
ELEVATION	N_0 = 6.3709325	N_3 = -2.9891376
	N_1 = -1.7095003	N_4 = 2.9417390
	N_2 = -4.6140394	

Before the coordinate conversion can be performed, the range from the MTR must be updated using the following equation:

$$R_m = \sum_{i=0}^{n} \alpha_i R_i$$

where

$n = 4$ $\alpha_0 = 1.5215871$ $\alpha_3 = -.13272919$

$\alpha_1 = -.35180884$ $\alpha_4 = .16204728$

$\alpha_2 = -.19909648$

If the data point were replaced by a predicted value, the predicted value should be used in the filter. The coefficient with subscript 0 multiplies the most recent data point.

The following coordinate system will be used for coordinate conversion: a right-hand cartesian coordinate system (X,Y,Z) centered at the NIKE-ZEUS launch pad, where the X-Y plane is tangent to the earth at the launch pad and the +X axis points down the launch azimuth, (218.5° T) and Z is normal to earth's surface at the launch pad. The equations used for coordinate conversion depend on the system being used.

Position data (X,Y,Z) and velocity data ($\dot{X},\dot{Y},\dot{Z}$, velocity) must be computed twenty times per second for each of the systems A, C and D, and must be computed on new data samples for system B.

The following equations are used in coordinate transformation:

$$X_P = (X_i \cos \theta - Y_i \sin \theta) - X_T$$

$$Y_P = (X_i \sin \theta + Y_i \cos \theta) - Y_T$$

where

X_i = X element of position measured tangent at the tracking instrument where +X is due east

Y_i = Y element of space position tangent at instrument with +Y pointing true north

$\sin\theta$ = sine of launch azimuth measured from true north
$\cos\theta$ = cosine of launch azimuth measured from true north

X_T = X element of position of instrument measured in pad coordinate system with + X = 218.5° T

Y_T = Y element of position of instrument measured in pad coordinate system with + Y = 128.5° T.

7 EDITING OF COMPUTED VALUES

The editing of computed values is good only if the following inequalities are satisfied. The computed velocities from each system must be edited using the following inequality:

$$V(t) - V(t - \Delta t) < \Delta V$$

where

$$\Delta V = C + C_1 R$$

and where C and C_1 are constants and R is range.

In addition, velocities of each good system must be compared using the following inequalities:

$$V_A - V_B < \Delta V_{AB}$$

$$V_A - V_D < \Delta V_{AD}$$

$$V_B - V_C < \Delta V_{BC}$$

$$V_B - V_D < \Delta V_{BD}$$

$$V_C - V_D < \Delta V_{CD}$$

where

A ≡ FPS-16/Cotar system
B ≡ MTR system
C ≡ Released FPS-16 system
D ≡ Free FPS-16 system

all ΔV's are of the form:

$$\Delta V = K + K_1 R$$

where K and K_1 are constants and R is range of high order system.

To help determine whether the FPS-16 radars (released and free) are tracking the booster or sustainer, $V_R < V_{min}$ must be satisfied. Where $V_{min} = 3500$ feet per second.

8 LOGIC FOR DETERMINING WHICH SYSTEMS ARE GOOD

The logic for determining which systems have good data is discussed in this section.

8.1 LOGIC USED FOR COTAR/FPS-16 SYSTEM

The items considered in determingin whether or not the data from this system are good are as follows: (1) the parity bits and ontarget from Cotar and FPS-16; (2) an edit of raw data C_1, C_2, and R_F; (3) an edit of missile velocity.

The following table describes the logic for determining whether system A has good data:

COTAR PARITY	COTAR QUALITY	FPS-16 PARITY	FPS-16 ONTARGET	EDIT $COS\alpha$	EDIT $COS\beta$	EDIT R_F	EDIT VEL	$COS^2\alpha+COS^2\beta$ > 1	$\sqrt{\Delta X^2+\Delta Y^2}$ $> \Delta P$	GOOD/ BAD
0	0	0	0	0	0	0	0	0	0	GOOD
Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	BAD
Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	Ø	
Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	Ø	Ø	
Ø	Ø	Ø	Ø	Ø	Ø	1	Ø	Ø	Ø	
Ø	Ø	Ø	Ø	Ø	1	Ø	Ø	Ø	Ø	
Ø	Ø	Ø	Ø	1	Ø	Ø	Ø	Ø	Ø	
Ø	Ø	Ø	1	Ø	Ø	Ø	Ø	Ø	Ø	
Ø	Ø	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	
Ø	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	
1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	BAD

where

0 = good
1 = bad
Ø = good or bad

8.2 LOGIC USED FOR MTR

The items considered in the MTR system are (1) parity bit; (2) an edit of raw data; (3) an edit of velocity; (4) check on time since last new data sample; (5) has coast been exceeded.

The following table describes the logic used in determining whether the MTR data is good or bad.

NEW DATA* BIT	PARITY	COAST**	EDIT RM	EDIT AM	EDIT EM	EDIT VEL	GOOD/BAD
0	0	0	0	0	0	0	GOOD
ø	ø	ø	ø	ø	ø	1	BAD
ø	ø	ø	ø	ø	1	ø	
ø	ø	ø	ø	1	ø	ø	
ø	ø	ø	1	ø	ø	ø	
ø	ø	1	ø	ø	ø	ø	
ø	1	ø	ø	ø	ø	ø	
1	ø	ø	ø	ø	ø	ø	BAD

* The new data bit check is good if the time since the last new data sample is 150 milliseconds or less.
** See documentation on maximum allowable coast.

8.3 LOGIC FOR RELEASED FPS-16

The items considered in the released FPS-16 system are (1) check of time from liftoff; (2) Cotar quality bit; (3) parity bit; (4) on-target bit; (5) edit of raw data; (6) missile velocity; (7) check of V vs V_{min}.

The following table describes the logic considered in determining whether system C is good or bad.

COTAR QUALITY	PARITY	ONTARGET	EDIT R	EDIT A	EDIT E	EDIT VEL	$V > V_{min}$	GOOD/ BAD
1	0	0	0	0	0	0	0	GOOD
ø	ø	ø	ø	ø	ø	ø	1	
ø	ø	ø	ø	ø	ø	1	ø	
ø	ø	ø	ø	ø	1	ø	ø	
ø	ø	ø	ø	1	ø	ø	ø	
ø	ø	ø	1	ø	ø	ø	ø	
ø	ø	1	ø	ø	ø	ø	ø	
ø	1	ø	ø	ø	ø	ø	ø	
0	ø	ø	ø	ø	ø	ø	ø	BAD

8.4 LOGIC FOR FREE FPS-16

The items considered for the free FPS-16 system D are (1) parity; (2) ontarget bit; (3) edit of raw data; (4) edit of velocity; (5) $V > V_{min}$.

The following table describes the logic in determining whether system D is good or bad.

PARITY	ONTARGET	EDIT R	EDIT A	EDIT E	EDIT V	$V > V_{min}$	GOOD/ BAD
0	0	0	0	0	0	0	GOOD
∅	∅	∅	∅	∅	∅	1	BAD
∅	∅	∅	∅	∅	1	∅	
∅	∅	∅	∅	1	∅	∅	
∅	∅	∅	1	∅	∅	∅	
∅	∅	1	∅	∅	∅	∅	
∅	1	∅	∅	∅	∅	∅	
1	∅	∅	∅	∅	∅	∅	BAD

9 LOGIC FOR DETERMINING WHICH SYSTEM SHOULD BE DISPLAYED AND USED FOR DESTRUCT LOGIC AND COMPUTATIONS

Once the status of the data from the four tracking systems has been established, the following logic is used to determine which of the four systems should be used for display outputs and destruct computations.

Information needed for this decision are as follows:

1. Is System A good?
2. Is System B good?
3. Is System C good?
4. Is System D good?
5. Which intersystem velocity comparisons are good?
6. Which system was chosen for previous sample?
7. Is the beacon-working signal good?

In the following table used for the logic in selecting the system, the nomenclature below is used.

A = COTAR/FPS-16
B = MTR
C = RELEASED FPS-16
D = FREE TRACK FPS-16

VELOCITY COMPARISONS					DATA						
AB	AD	BC	BD	CD	A	B	C	D	BEACON	PRE SYSTEM	SELECTED SYSTEM
					1	1	1	1	Ø	A	A
					1	1	1	1	Ø	B	B
					1	1	1	1	Ø	C	C
					1	1	1	1	Ø	D	D
					1	1	1	0	Ø	Ø	D
					1	1	0	1	Ø	Ø	C
				1	1	1	0	0	Ø	A+B+C	C
				1	1	1	0	0	Ø	D	D
				0	1	1	0	0	Ø	Ø	C
					1	0	1	1	Ø	Ø	B
			1		1	0	1	0	0	A+B+C	B
			1		1	0	1	0	0	D	D
			1		1	0	1	0	1	Ø	D
			0		1	0	1	0	0	Ø	B
			0		1	0	1	0	1	Ø	D
		1			1	0	0	1	0	A+B+C	B
		1			1	0	0	1	0	C	C
		1			1	0	0	1	1	Ø	C
		0			1	0	0	1	0	Ø	B
		0			1	0	0	1	1	Ø	C
		1	1	1	1	0	0	0	0	A+B	B
		1	1	1	1	0	0	0	0	C	C
		1	1	1	1	0	0	0	0	D	D
		1	1	1	1	0	0	0	1	A+B+C	C
		1	1	1	1	0	0	0	1	D	D
		1	1	0	1	0	0	0	Ø	Ø	C
		1	0	1	1	0	0	0	0	Ø	B
		1	0	1	1	0	0	0	1	A+B+C	C
		1	0	1	1	0	0	0	1	D	D
		1	0	0	1	0	0	0	0	Ø	B
		1	0	0	1	0	0	0	1	Ø	C
		0	1	1	1	0	0	0	0	Ø	B
		0	1	1	1	0	0	0	1	A+B+C	C
		0	1	1	1	0	0	0	1	D	D
		0	1	0	1	0	0	0	0	Ø	B
		0	1	0	1	0	0	0	1	Ø	C
		0	0	1	1	0	0	0	0	Ø	B
		0	0	1	1	0	0	0	1	A+B+C	C
		0	0	1	1	0	0	0	1	D	D
		0	0	0	1	0	0	0	0	Ø	B
		0	0	0	1	0	0	0	1	Ø	C
					0	1	1	1	Ø	Ø	A
	1				0	1	1	0	Ø	A+B+C	A
	1				0	1	1	0	Ø	D	D
	0				0	1	1	0	Ø	Ø	A

VELOCITY COMPARISONS					DATA					PRE	SELECTED
AB	AD	BC	BD	CD	A	B	C	D	BEACON	SYSTEM	SYSTEM
1					0	0	1	1	0	A+C+D	A
1					0	0	1	1	0	B	B
1					0	0	1	1	1	Ø	A
0					0	0	1	1	Ø	Ø	A
1	1		1		0	0	1	0	0	A+C	A
1	1		1		0	0	1	0	0	B	B
1	1		1		0	0	1	0	0	D	D
1	1		1		0	0	1	0	1	A+B+C	A
1	1		1		0	0	1	0	1	D	D
1	1		0		0	0	1	0	0	Ø	B
1	1		0		0	0	1	0	1	A+B+C	A
1	1		0		0	0	1	0	1	D	D
1	0		1		0	0	1	0	Ø	Ø	A
1	0		0		0	0	1	0	Ø	Ø	A
0	1		1		0	0	1	0	0	Ø	A
0	1		1		0	0	1	0	1	A+B+C	A
0	1		1		0	0	1	0	1	D	D
0	1		0		0	0	1	0	0	Ø	A
0	1		0		0	0	1	0	1	A+B+C	A
0	1		0		0	0	1	0	1	D	D
0	0		1		0	0	1	0	Ø	Ø	A
0	0		0		0	0	1	0	Ø	Ø	A

where 0 - good   1 - bad   Ø - either good or bad.

where the item is left blank - not computed.

10 INSTANTANEOUS IMPACT PREDICTION

Instantaneous impact point (IIP) is defined as the predicted point of impact of the missile parts if the missile were destroyed at the instant.

10.1 IIP EQUATION

The IIP of only the heaviest expected part ($\frac{\omega}{C_D S}$ = 165 lb/ft^2) will be computed. The impact point of this part is given as follows:

$$X_i = r \cos \beta + X$$

$$Y_i = r \sin \beta + Y$$

where $\beta = \tan^{-1} \frac{Y'}{X'}$

The value r (range to impact) is stored in the computer as a function of velocity, missile heading angle and height above launch pad Z. The least significant bit of r is equal to 500 feet, therefore carry range can only be accurate to $\pm$ 500 feet.

10.2 VELOCITY AND HEADING ANGLE EQUATIONS

The equations for determining the velocity and heading angle of the missiles are:

$$\text{Velocity} = \sqrt{\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2}$$

$$\text{Missile heading angle} = \tan^{-1} \frac{Z'}{\sqrt{X'^2 + Y'^2}}$$

Z' = height of the missile above the tangent plane at the launch pad.

10.3 RANGE TO IMPACT TABLE

A description of the range to impact tables follows. The table is stored as a function of V_1, γ_1, Z_1.

RANGE OF VARIABLES

V_1 0 to 12,000 ft/sec

γ_1 -30 deg to + 90 deg

Z_1 0 to 400,000 feet

SIZE OF INCREMENTS

V_1 2000 ft/sec

γ_1 5 deg.

Z_1 10,000 feet

NUMBER OF VALUES

V_1 7

γ_1 25

Z_1 41

The total storage necessary is 7175 cells.

10.4 INTERPOLATION

Linear interpolation is used in γ_1 and V_1, and parabolic interpolation in Z_1 to determine r when initial conditions lie between stored values. When initial conditions lie outside the table of stored values, the end point of the table is used.

For interpolation from the stored tables, parabolic interpolation is used for one variable, and linear interpolation is used for two variables.

The following is an example of parabolic interpolation of Z:

If $Z = 13{,}000$ feet

$$a_Z = \frac{Z - Z_1}{H_Z}$$

$$a_Z = \frac{13{,}000 - 10{,}000}{10{,}000} \; ; \; Z_0 = 0;\ Z_1 = 10{,}000;\ Z_2 = 20{,}000;\ Z_3 = 30{,}000$$

$$H_Z = 10{,}000$$

Steps: 1) test a_Z if $a_Z \leq .5$, use Z_0, Z_1, Z_2

if $a_Z > .5$, use Z_1, Z_2, Z_3

2) determine appropriate values of

R_{VW}, γ_X, Z_Y from tables for example:

$R_{V_1\gamma_1 Z_0}$ $\quad R_{V_1\gamma_1 Z_1}$ $\quad R_{V_1\gamma_1 Z_2}$

$$R_{V_2\gamma_1 Z_0} \quad R_{V_2\gamma_1 Z_1} \quad R_{V_2\gamma_1 Z_2}$$

$$R_{V_1\gamma_2 Z_0} \quad R_{V_1\gamma_2 Z_1} \quad R_{V_1\gamma_2 Z_2}$$

$$R_{V_2\gamma_2 Z_0} \quad R_{V_2\gamma_2 Z_1} \quad R_{V_2\gamma_2 Z_2}$$

3) perform linear interpolation of one variable:

example: $R_{V\gamma_1 Z_0} = R_{V_1\gamma_1 Z_0} + a_V(R_{V_2\gamma_1 Z_0} - R_{V_1\gamma_1 Z_0})$

determine $R_{V\gamma_{1\to 2}} \quad Z_{0\to 2}$

4) perform second linear interpolation:

example: $R_{V\gamma Z_0} = R_{V\gamma_1 Z_0} + a_\theta(R_{V\gamma_2 Z_0} - R_{V\gamma_1 Z_0})$

determine $R_{V\gamma Z_{0\to 2}}$

5) perform parabolic interpolation to determine carry range to impact:

example: $$R_{V\gamma Z} = R_{V\gamma Z_1} + a_Z(R_{V\gamma Z_2} - R_{V\gamma Z_1}) + \frac{(a_Z)(1 - a_Z)}{2} [R_{V\gamma Z_0} - 2 R_{V\gamma Z_1} + R_{V\gamma Z_2}]$$

Note: if $a_Z \geq .5$ and consequently Z_3 was used, formula for parabolic interpolation changes to the following:

$$R_{V\gamma Z} = R_{V\gamma Z_3} + a_Z(R_{V\gamma Z_4} - R_{V\gamma Z_3}) + \frac{(a_Z)(1 - a_Z)}{2} [R_{V\gamma Z_1} - 2 R_{V\gamma Z_2} + R_{V\gamma Z_3}]$$

10.5 EQUATIONS FOR COMPUTING RANGE TO IMPACT USING TABLE

The following are the equations used for computing range to impact using table.

Problem: Find $R_i = f(Z,V,\theta)$ from a table of R at even intervals of Z,V,θ with linear interpolation of the variables V,θ and parabolic interpolation of Z.

The tabular values are Z; 10,000 ft $= H_Z$

V; 2,000 ft/sec $= H_V$

θ; $5^\circ = H_\theta$

$$a_\theta = \frac{\theta - \theta_1}{H_\theta} \qquad a_V = \frac{V - V_1}{H_V} \qquad a_Z = \frac{Z - Z_1}{H_Z}$$

if $a_Z \le .5$ use example 1

if $a_Z > .5$ use example 2

Example 1. find $f(Z,V,\theta)$ where $Z_1 \le Z < Z_2$

$$V_1 \le V < V_2$$

$$\theta_1 \le \theta < \theta_2$$

From the table get the following values if $R_{i,j,k} = f(Z_i,V_j,\theta_k)$

$R_{1,1,1}$	$R_{2,1,1}$	$R_{3,1,1}$
$R_{1,1,2}$	$R_{2,1,2}$	$R_{3,1,2}$
$R_{1,2,1}$	$R_{2,2,1}$	$R_{3,2,1}$
$R_{1,2,2}$	$R_{2,2,2}$	$R_{3,2,2}$

Compute with linear interpolation

$$S_{1,1} = R_{111} + a_\theta(R_{112} - R_{111}) \qquad S_{2,2} = R_{221} + a_\theta(R_{222} - R_{221})$$

$$S_{1,2} = R_{121} + a_\theta(R_{122} - R_{121}) \qquad S_{3,1} = R_{311} + a_\theta(R_{312} - R_{311})$$

$$S_{2,1} = R_{211} + a_\theta(R_{212} - R_{211}) \qquad S_{3,2} = R_{321} + a_\theta(R_{322} - R_{321})$$

and $S_1 = S_{11} + a_V(S_{12} - S_{11})$

$$S_2 = S_{21} + a_V(S_{22} - S_{21})$$

$$S_3 = S_{31} + a_V(S_{32} - S_{31})$$

Compute with parabolic interpolation

$$R_i = S_1 + a_Z(S_2 - S_1) + \frac{a_Z(a_Z - 1)}{2}(S_1 - 2S_2 + S_3)$$

Example 2: If $a_Z > .5$ use the following values

$R_{0,1,1}$	$R_{0,2,1}$	$R_{1,1,1}$	$R_{1,2,1}$	$R_{2,1,1}$	$R_{2,2,1}$
$R_{0,1,2}$	$R_{0,2,2}$	$R_{1,1,2}$	$R_{1,2,2}$	$R_{2,1,2}$	$R_{2,2,2}$

$$S_{0,1} = R_{0,1,1} + a_\theta(R_{012} - R_{011}) \qquad S_{1,2} = R_{121} + a_\theta(R_{122} - R_{121})$$

$$S_{0,2} = R_{0,2,1} + a_\theta(R_{022} - R_{021}) \qquad S_{2,1} = R_{211} + a_\theta(R_{212} - R_{211})$$

$$S_{1,1} = R_{1,1,1} + a_\theta(R_{112} - R_{111}) \qquad S_{2,2} = R_{221} + a_\theta(R_{222} - R_{221})$$

$$S_0 = S_{01} + a_V(S_{02} - S_{01})$$

$$S_1 = S_{11} + a_V(S_{12} - S_{11})$$

$$S_2 = S_{21} + a_V(S_{22} - S_{21})$$

change $a_Z = \dfrac{Z - Z_1}{H_Z}$

to $a_Z = \dfrac{Z - Z_2}{H_Z}$

$$R_i = S_2 + a_Z(S_2 - S_1) + \frac{a_Z(a_Z + 1)}{2}(S_0 - 2S_1 + S_2)$$

The following items are necessary for making destruct decisions regardless of which system is used.

(1) If, during the time interval defined by $5.2 < t < 16$ seconds, $\dot{X}$ computed by using data from the selected system falls below prescribed minimum, $\dot{X}_{min}$, destruct should be commanded on this sample, i.e.:

$$\dot{X} < \dot{X}_{min} \text{ command destruct}$$

$\dot{X}_{min}$ is an increasing ramp computed from missile position and time liftoff.

(2) If, during the interval between 5.2 seconds after liftoff and the time when X, the present position of the missile, reaches 300,000 feet down range, the predicted impact point lies outside of the imposed range safety boundaries, the signal for destruct is sent immediately.

11.1 MAXIMUM ALLOWABLE COAST

Maximum allowable coast time is a function of C_{min} no data time. On the sample where MTR coast occurs, C_{min} begins counting down to zero. Therefore, the maximum coast time is the amount of no data time computed when coast is initiated.

11.2 NECESSARY INPUTS FOR COMMAND DESTRUCT

X, Y, Z

$\dot{X}, \dot{Y}, \dot{Z}$

$\cos \beta = X \sqrt{\dot{X}^2 + \dot{Y}^2}$

t_{CL} = time from liftoff

X = impact point

R_C = carry range

11.3 STEPS IN THE AUTOMATIC DESTRUCT PROGRAM

1. Is data good?

   Yes → 2

   No → 62

2. Is system A good?

   Yes - use "a" constants → 4

   No → 3

3. Is MTR good?

   Yes - use "b" constants → 4

   No - use "c" constants → 4

4. Is $t_{CL} < K_1$?

   Yes → 67

   No → 5

5. Is $t_{CL} < K_2$?

   Yes → 6

   No - store $C_{D1} = C_{D2} = K_{10}$ → 16

6. Compute $X_D = K_3 + K_4 Z$

7. Is $X < X_D$?

   Yes → 65

   No → 8

8. Compute $C_1 = \dfrac{(Z\dot{X} - \dot{Z}X_D) + [(Z\dot{X} - \dot{Z}X_D)^2 + 2Z^2(X - X_D)K_5]^{\frac{1}{2}}}{ZK_5}$

9. Compute $C_{D1} = C_1 - K_{6i}$ $(C_{D1} \leq 0)$

10. Store C_{D1}

11. Compute $X_D = \dfrac{K_{7i}Z + K_{8i}}{Z + K_{9i}}$

12. Is $\dot{X} < \dot{X}_D$?

Yes → 65

No → 13

13. Compute $C_{D2} = \dfrac{\dot{X} - \dot{X}_D}{K_5}$

14. Store C_{D2}

15. Is $t_{CL} < K_{11}$?

16. Is $R_C < K_{12}$?

Yes → 17

No → 25

17. Compute $\tan D_{R1} = K_{39} + \dfrac{K_{40}}{R_C}$

18. Is $\dot{Y} + K_{15i} \cos \beta < \dot{X} \tan D_{R1}$?

Yes → 65

No → 18a

18a. Is $t_{CL} > K_{38}$?

Yes → 18b

No → 19

18b. Compute $C_R = \dfrac{(\dot{Y} + K_{22i} \cos\beta) - (\dot{X} \tan D_{R2})}{K_{23}}$

18c. Store C_R → 21

19. Compute $C_R = \dfrac{(\dot{Y} + K_{15i} \cos\beta) - (\dot{X} \tan D_{R1})}{K_{16}}$

20. Store C_R

21. Compute $\tan D_{L1} = K_{41} + \dfrac{K_{42}}{R_C}$

22. Is $\dot{Y} + K_{18i} \cos\beta < \dot{X} \tan D_{L1}$?

Yes → 23

No → 65

23. Compute $C_L = \dfrac{(\dot{X} \tan D_{L1}) - (\dot{Y} + K_{18i} \cos\beta)}{K_{16}}$

24. Store $C_L \rightarrow 52$

25. Is $X < K_{19}$?

Yes → 26

No → 34

26. Compute $\tan D_{R2} = \frac{K_{20}}{K_{21}}$

27. Is $\dot{Y} + K_{22i}\cos\beta < \dot{X}\tan D_{R2}$?

Yes → 65

No → 28

28. Compute $C_R = \frac{(\dot{Y} + K_{22i}\cos\beta) - (\dot{X}\tan D_{R2})}{K_{23}}$

29. Store C_R

30. Compute $\tan D_{L2} = K_{41} + \frac{K_{42}}{R_C}$

31. Is $\dot{Y} + K_{25i}\cos\beta < \dot{X}\tan D_{L2}$?

Yes → 32

No → 65

32. Compute $C_L = \frac{(X\tan D_{L2}) - (Y + K_{25i}\cos\beta)}{K_{23}}$

33. Store $C_L \rightarrow 52$

34. Is $X < K_{26}$?

Yes → 35

No → 66

35. Is $Z < K_{27}$?

Yes → 36

No → 44

36. Compute $\tan D_{R3} = \frac{K_{28}}{K_{29}}$

37. Is $\dot{Y} + K_{30i}\cos\beta < \dot{X}\tan D_{R3}$?

Yes → 65

No → 38

38. Compute $C_R = \dfrac{(\dot{Y} + K_{30i}\cos\beta) - (\dot{X}\tan D_{R3})}{K_{31}}$

39. Store C_R

40. Compute $\tan D_{L3} = K_{41} + \dfrac{K_{42}}{R_C}$

41. Is $\dot{Y} + K_{33i}\cos\beta < \dot{X}\tan D_{L3}$?

Yes → 42

No → 65

42. Compute $C_L = \dfrac{(\dot{X}\tan D_{L3}) - (\dot{Y} + K_{33i}\cos\beta)}{K_{31}}$

43. Store C_L → 52

44. Compute $\tan D_{R4} = \dfrac{K_{28}}{K_{29}}$

45. Is $\dot{Y} + K_{34i}\cos\beta < \dot{X}\tan D_{R4}$?

Yes → 65

No → 46

46. Compute $C_R = \dfrac{(\dot{Y} + K_{34i}\cos\beta) - (\dot{X}\tan D_{R4})}{K_{35}}$

47. Store C_R

48. Compute $\tan D_{L4} = K_{41} + \dfrac{K_{42}}{R_C}$

49. Is $\dot{Y} + K_{36i}\cos\beta < \dot{X}\tan D_{L4}$?

Yes → 50

No → 65

50. Compute $C_L = \dfrac{(\dot{X}\tan D_{L4}) - (\dot{Y} + K_{36i}\cos\beta)}{K}$

51. Store C_L

52. Is $C_{D1} < C_{D2}$

Yes → 53

No → 55

53. Is $C_{D1} < C_R$?

Yes → 54

No → 57

54. Is $C_{D1} < C_L$?

Yes → 58

No → 57

55. Is $C_{D2} < C_R$?

Yes → 56

No → 57

56. Is $C_{D2} < C_L$?

Yes → 59

No → 61

57. Is $C_R < C_L$?

Yes → 60

No → 61

58. Store C_{D1} = Cmin → 64

59. Store C_{D2} = Cmin → 64

60. Store C_R = Cmin → 64

61. Store C_L = Cmin → 64

62. Compute $\text{Cmin}_{(\text{new})} = \text{Cmin} - K_{37}$

63. Is $\text{Cmin}_{(\text{new})} < 0$

Yes → 64

No → 65

64. Store $\text{Cmin}_{(\text{new})}$ for previous Cmin → 67

65. Command destruct → 67

66. Turn off automatic destruct

67. Perform Impact computations for next sample

Note: Cmin is defined as maximum allowable no data time.

11.4 DEFINITION OF CONSTANTS

K_1 = 5.2 seconds	K_2 = 20 seconds	
K_3 = -850 feet	K_4 = .32426	
K_5 = 710 feet/sec^2		
K_{6a} = 1.2778	K_{6b} = 1.5593	K_{6c} = 1.7638 (sec)
K_{7a} = 1165	K_{7b} = 1205	K_{7c} = 1305 (ft/sec)
K_{8a} = 12.135x10^6	K_{8b} = 8.87x10^6	K_{8c} = 4.995x10^6 (ft^2/sec)
K_{9a} = 19000	K_{9b} = 14000	K_{9c} = 9000 feet
K_{10} = 10 seconds	K_{11} = 6.5 seconds	K_{12} = 49000 feet
K_{13} = -71150 feet	K_{14} = 74500 feet	
K_{15a} = -805	K_{15b} = -933	K_{15c} = -905 (ft/sec)
K_{16} = 633 ft/sec^2	K_{17} = 71150 feet	
K_{18a} = 805	K_{18b} = 933	K_{18c} = -905 (ft/sec)
K_{19} = 35000 feet	K_{20} = -103450 feet	K_{21} = 158700 feet
K_{22a} = =865	K_{22b} = -940	K_{22c} = -963 (ft/sec)
K_{23} = 678 ft/sec	K_{24} = 131900 feet	
K_{25a} = 865	K_{25b} = 940	K_{25c} = 963 (ft/sec)
K_{26} = 300000 feet	K_{27} = 100000 feet	K_{28} = -177800 feet
K_{29} = 256000 feet		
K_{30a} = -902	K_{30b} = -1010	K_{30c} = -1000 (ft/sec)
K_{31} = 710 ft/sec	K_{32} = 202000 feet	

$K_{33a} = 902$ $K_{33b} = 1010$ $K_{33c} = 1000$ (ft/sec)

$K_{34a} = -570$ $K_{34b} = -640$ $K_{34c} = -670$

$K_{35} = 450$ ft/sec^2

$K_{36a} = 570$ $K_{36b} = 640$ $K_{36c} = 670$ (ft/sec)

$K_{37} = .05$ seconds $K_{38} = 9.5$ seconds $K_{39} = -1.11$

$K_{40} = -5000$ feet $K_{41} = .71$ $K_{42} = 20000$ feet

OUTPUT INFORMATION

The following are outputs from the computer:

A. Plot board displays

X vs. Y, X vs. Z, $\dot{X}$ vs. $\dot{Y}$, $\dot{X}$ vs. $\dot{Z}$, short range and long range X impact vs. Y impact.

Note: X is measured positive along the launch azimuth (218.5°T), and Y is measured positive at 128.5°T.

B. Missile destruct control (destruct signal required)

The destruct signal must be compatible with the digital-to-analog converter. A signal is sent for both destruct commands and do not destruct commands.

C. Data quality lights

The following two-level outputs must be provided for quality light control:

1. Indication of good or bad data from the PMR systems. A, C, or D.

2. Indication of good or bad data from system B, the MTR system.

D. History tape

The following information is recorded, in real time, to make a launch history tape for postflight reduction and future launch simulation.

Words 1-30 - Raw Input Tracking Data

31 - Liftoff Time

32 - Time from Liftoff

33 - PMR Range Time

34 - Clock Time

35 - Sense Switch Settings

36 - Entry Key Settings

37 - Data Indicator Word

38 - Sense Lights

39 - X System A

40 - Y System A

41 - Z System A

42 - $\dot{X}$ System A

43 - $\dot{Y}$ System A

44 - $\dot{Z}$ System A

45 - Velocity System A

46 - X System B

47 - Y System B

48 - Z System B

49 - $\dot{X}$ System B

50 - $\dot{Y}$ System B

51 - $\dot{Z}$ System B

52 - Velocity System B

53 - X System C

54 - Y System C

55 - Z System C

56 - $\dot{X}$ System C

57 - $\dot{Y}$ System C

58 - $\dot{Z}$ System C

59 - Velocity System C

60 - X System D

61 - Y System D

62 - Z System D

63 - $\dot{X}$ System D

64 - $\dot{Y}$ System D

65 - $\dot{Z}$ System D

66 - Velocity System D

67 - X Impact Component

68 - Y Impact Component

69 - C1 Flag: if = 0, System A is good; $\neq$ 0, System A bad

70 - C2 Flag: if = 0, System B is good; $\neq$ 0, System B bad

71 - C3 Flag: if = 0, System C is good; $\neq$ 0, System C bad

72 - C4 Flag: if = 0, System D is good; $\neq$ 0, System D bad

73 - C5 Flag: if = 0, System A ontarget; $\neq$ 0, System A not ontarget

74 - C6 Flag: if = 0, System B ontarget; $\neq$ 0, System B not ontarget

75 - C7 Flag: if = 0, System C ontarget; $\neq$ 0, System C not ontarget

76 - C8 Flag: if = 0, System D ontarget; $\neq$ 0, System D not ontarget

77 - C9 Flag: Δ Vel System A; $\neq$ 0, bad; = 0, good

78 - C10 Flag: $\triangle$ Vel System B; $\neq 0$, bad; $= 0$, good

79 - C11 Flag: $\triangle$ Vel System C; $\neq 0$, bad; $= 0$, good

80 - C12 Flag: $\triangle$ Vel System D; $\neq 0$, bad; $= 0$, good

81 - C13 Flag: $= 0$, beacon good; $\neq 0$, beacon bad

82 - C14 Flag: Intersystem Vel Comparison AB; $= 0$, good; $\neq 0$, bad

83 - C15 Flag: Intersystem Vel Comparison AD; $= 0$, good; $\neq 0$, bad

84 - C16 Flag: Intersystem Vel Comparison BC; $= 0$, good; $\neq 0$, bad

85 - C17 Flag: Intersystem Vel Comparison BD; $= 0$, good; $\neq 0$, bad

86 - C18 Flag: Intersystem Vel Comparison CD; $= 0$, good; $\neq 0$, bad

87 - C19 Flag: Previous System Switch Switch; 0 = System A, 1 = System B, 2 = System C, 3 = System D

88 - C20 Flag: Interprogram

89 - C21 Flag: Interprogram

90 - C22 Flag: X test; 0 = good, non-zero = bad

91 - C23 Flag; + Y Boundary; 0 = good; $\neq 0$, bad

92 - C24 Flag; -Y Boundary; 0 = good; $\neq 0$, bad

93 - C25 Flag; Overall Data Quality; $= 0$, good; $\neq 0$, bad

94 - C26 Flag; Has liftoff occurred; $= 0$, yes; $\neq 0$, no

95 - C27 Flag; Lockout indicator; has lockout occurred; $= 0$, no, $\neq 0$, yes

96 - C28 Flag; New data MTR; $= 0$, yes; $\neq 0$, no

97 - C29 Flag; Position check; $= 0$, good; $\neq 0$, bad

98 - C31 Flag; Interprogram switch

99 - C32 Flag; Interprogram switch

100 - $\dot{X}$ vs $\dot{Z}$ converter output setting

101 - $\dot{X}$ vs $\dot{Y}$ converter output setting

102 - X vs. Z converter output setting

103 - X vs. Y converter output setting

104 - X_{imp} vs. Y_{imp} converter output setting long range

105 - X_{imp} vs. Y_{imp} converter output setting short range

106 - Time vs. Liftoff converter output setting

107 - Destruct Word converter output setting

108 - Gamma Angle PMR System

109 - Beta Angle PMR System

110 - Gamma Angle MTR System

111 - Beta Angle MTR System

112 - Type Destruct

113 - Indicator data word

114 - Cosine Alpha from Cotar

115 - Cosine Beta from Cotar

116 - Cosine Gamma from Cotar

117 - C_{min}; maximum no data time

118 - X_D; X position roof component

13 EXTERNAL SWITCHES

13.1 ENTRY KEY SELECTION FOR FPS-16 SYSTEM SELECTION

KEYS 1 - 2 - 3 - 4 - 5 (KEYS DOWN)

SLAVE RADAR ID	DMS CHANNEL 1	DMS CHANNEL 4	DMS CHANNEL 5	DMS CHANNEL 6
003001	None	3	2	2,3
003002	5	3,5	2,5	2,3,5
003003	4	3,4	2,4	2,3,4
003004	4,5	3,4,5	2,4,5	2,3,4,5

KEYS 7 - 8 - 9 - 10 - 11 (KEYS DOWN)

FREE TRACK RADAR ID	DMS CHANNEL 1	DMS CHANNEL 4	DMS CHANNEL 5	DMS CHANNEL 6
003001	None	9	8	8,9
003002	11	9,11	8,11	8,9,11
003003	10	9,10	8,10	8,9,10
003004	10,11	9,10,11	8,10,11	8,9,10,11

13.2 SENSE SWITCH SELECTION

PROGRAM I = Main program operating in real time

PROGRAM II = Communication program for auxiliary programs for pre-flight and postflight

PROGRAM III = Region for equipment checkout

PROGRAM I

SENSE SWITCHES	1	2	3	4	5	6	7	8	9
UP	SIMULATE FROM TAPE		NO PLOT			RECORD			
DOWN				TERMINATE	EXIT TO PROG II	NO RECORD	FORCE SYSTEM A	FORCE SYSTEM B	FORCE SYSTEM D

PROGRAM I (cont'd)

SENSE SWITCHES	10	11	12
UP		REWIND	
DOWN	FORCE SYSTEM D1	NO REWIND D1	FORCE PLOT COTAR FLIGHT

PROGRAM II

SENSE SWITCHES	7	8	10	11
UP				
DOWN	EXIT TO PRINTOUT	EXIT TO PROGRAM III	EXIT TO TAPE COMPARE ROUTINE	EXIT TO PROGRAM I

PROGRAM III

SENSE SWITCHES	1	2	3	4	8	11
UP	PMR RED LIGHT	MTR RED LIGHT	NO DESTRUCT	NO CLOVER	EXIT TO PROGRAM II	
DOWN	PMR GREEN LIGHT	MTR GREEN LIGHT	DESTRUCT COMMAND	PLOT CLOVER LEAF		EXIT TO PROGRAM I

During a real time operation, the first step is to select the input equipment and to read in 30 words of raw data, which is the basic block of data information from the tracking instruments. Since the tracking information enters the buffer system at the rate of 20 samples per second, the next 30 words of data will appear approximately a 20th of a second later. Therefore, all computations must be completed in this time period.

The successful transmission of data from the input system into core storage of the computer will be signaled by the input system through an end of record pulse. As soon as this pulse has been detected by the computer, the computation involving use of these 30 words begins.

As a preliminary step, the parity, ontarget, quality and data editing limits are checked. This provides information as to the quality of the incoming data. Time is converted from the raw data format in which it was input, into a suitable decimal format. The Cotar direction cosines are then converted to a usable decimal format along with the range, azimuth, and elevation from the two FPS-16's and the MTR.

If missile lift-off has occurred as shown by the lift-off indicator, a lift-off flag is set for the program. If a lockout has occurred, all raw tracker information must be predicted and the raw input data is ignored.

After converting raw data to a usable decimal format, the Cotar cosines are edited. If the sum of the squares of cosine alpha and cosine beta is greater than 1, Cotar data is flagged bad, and therefore the Cotar cosines will not be predicted; thus System A is flagged bad. Next, if the cosines have passed the previously mentioned test, the range from the Cotar to the missile is computed. The cosine information from the Cotar and the range, azimuth and elevation from all radars are then fed into the differentiator, which computes the components required for velocity computations for systems A, B, C, D. The present position and velocity components are then computed for all systems.

The next steps are essential to the logic, involving the decision to destroy or not to destroy. All flags pertaining to this phase have been set in the main program; these flags are based on data quality, editing limits, and velocity limits imposed in the program.

The changes in velocities are checked next. If the change in velocity ΔV_{cp} (for any particular system, A, B, C, or D) between the current velocity V_c and the previous velocity V_p exceeds the normal change in velocity ΔV_n for the current position of the missile, the current velocity V_c is flagged bad for that particular system. This relationship may be expressed by the inequality below:

If

$$\Delta V_{cp} < \Delta V_n$$

where

$$\Delta V_{cp} = V_c - V_p$$

then V_c is flagged bad.

The logic for determining the system to be used for destruct also includes an intersystem velocity comparison. If System A is good, then System C is automatically flagged good, and no intersystem velocity comparison is made for Systems A and C. Therefore, we have intersystem velocity comparisons with A and B, A and D, B and C, B and D, and C and D. If all systems are flagged bad, then the system used for the previous sample will be used for destruct logic.

When the program has finally determined which system is to be used for destruct logic, the position data from that system is used to compute instantaneous impact point.

After all computations have been made of the missile position, velocity, and impact point, the decision is made whether the missile should be destroyed. Then, all outputs are sent from the computer to the plot boards and to data quality lights; and a "destruct" or "do not destruct" command is sent to the Target Intercept Computer (TIC). All raw and computed information is then recorded on a flight history tape and the program recycles, returning to the beginning for another data sample.

GLOSSARY

A	$\equiv$	azimuth
a, a_i, a_0, etc.	$\equiv$	coefficients
C	$\equiv$	constant
C_1	$\equiv$	constant other than C
C_1	$\equiv$	Cotar cosine α
C_2	$\equiv$	Cotar cosine β
C_{min}	$\equiv$	maximum allowable no data time
E	$\equiv$	elevation
fb	$\equiv$	Cotar base frequency
K	$\equiv$	constant
K_1	$\equiv$	constant other than K
K_0	$\equiv$	coefficient
K_c	$\equiv$	frequency correction
K_r	$\equiv$	Cotar operating frequency
R	$\equiv$	range
R_c	$\equiv$	carry range
R_t	$\equiv$	current range time
$R_{t_{LO}}$	$\equiv$	range time at lift off
t	$\equiv$	time
t_{CL}	$\equiv$	time from lift off
Δt	$\equiv$	increment of time
$(t - \Delta t)$	$\equiv$	time of previous point
V	$\equiv$	velocity

ΔV ≡ change in velocity

V_A ≡ velocity determined from System A

V_B ≡ velocity determined from System B

V_C ≡ velocity determined from System C

V_D ≡ velocity determined from System D

V_{min} ≡ prescribed minimum velocity

X ≡ X-coordinate

$(\dot{X}, \dot{Y}, \dot{Z})$ ≡ velocity data

X_i ≡ X element of position measured tangent at tracking instrument when +X is due east

X_T ≡ X element of position of instrument measured in pad coordinate system with +X = 218.5° T

$\dot{X}$ ≡ velocity component along X-axis

Y ≡ Y-coordinate

$\dot{Y}$ ≡ velocity component along Y-axis

Y_i ≡ Y element of space position tangent at instrument with +Y pointing true north

Y_T ≡ Y element of position of instrument measured in pad coordinate system with +Y = 128.5° T

Z ≡ Z-coordinate

Z' ≡ height of missile above tangent plane at launch pad

$\dot{Z}$ ≡ velocity component along Z-axis

α, β, γ ≡ direction angles

$\alpha_1, \alpha_i, \alpha_0$ etc. ≡ coefficients

θ ≡ azimuth (from true north)

ϕ ≡ elevation (from true north)

ω ≡ frequency correction

Subscripts:

A	≡	System A	≡	Cotar/FPS-16
B	≡	System B	≡	MTR
C	≡	System C	≡	Released FPS-16
D	≡	System D	≡	Free FPS-16
PRED	≡	Predicted		
M	≡	MTR		
F	≡	FPS-16		
T	≡	true		
t	≡	time		
LO	≡	lift off		

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Land-Air, Inc., Point Mugu, Calif.
NIKE-ZEUS AUTOMATIC DESTRUCT RANGE SAFETY PROGRAM by T. Rickman and R. Holguin, ed. by T. Wakai. Report on programing for the IBM 7090 Computer. (Report No. 36)
21 Nov 62. 63 pages incl. illus.
(Contract N-123(61756)19425A/PMR) Unclassified Report

The Program for the IBM 7090 Computer accomodates a considerable increase in redundant tracking information and embodies refinement in logic not found in the program built for the IBM 709 computer, as described in Land-Air, Inc. Report No. 26.

The Pacific Missile Range System which inputs data to the IBM 7090 Computer at 20 samples per second consists of (1) a Cotar which outputs direction cosines α and β, (2) an AN/FPS-16 radar that is slaved to the Cotar and which outputs range only, and (3) a second AN/FPS-16 radar that is free to skin-track and output polar coordinate data, becoming another source of input to the computer. A fourth source of data is the Missile Tracking Radar which outputs raw polar data at the rate of 8.123 samples per second.

The single system chosen by the program to control destruct

UNCLASSIFIED

1. Impact Computer
2. Programing
3. Mathematical Computer Control Systems
4. Radar Ranging Systems

I. Rickman, T. and R. Holguin, auth.;
II. Wakai, T. ed.
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The computer output consists of predicted missile impact location, present position, velocity, acceleration displayed at a remote location. The same output and also all raw input data are recorded on tape for postflight usage.

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